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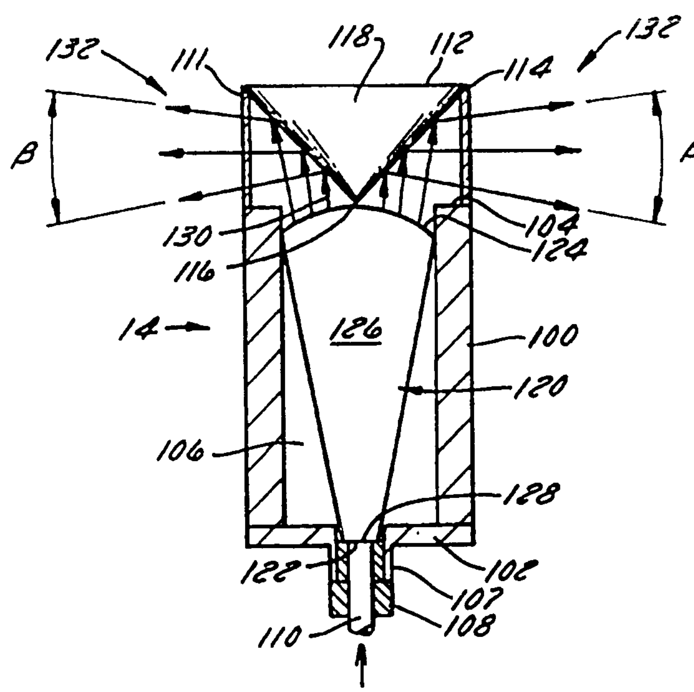
(54) Title: BEAMFORMER FOR A REMOTELY ILLUMINATED LIGHTING SYSTEM AND METHOD

(57) Abstract

A remotely illuminated lighting system distributes from a central illumination source light signals to remote light distribution devices (14). Each remote light distribution device (14) or beamformer, is adaptable to produce a highly precise distribution pattern (132) from the light signals. The distribution pattern (132) may be easily adjusted in both horizontal and vertical directions. In a first preferred arrangement, each beamformer is coupled via a fiber-optic cable to the central light source and includes a non-imaging light transformer (120) and a conical reflective element (112). In additional preferred embodiments, a holographic diffuser and/or a masking element are incorporated for adapting the shape of the light distribution pattern. An electronically controlled masking element may be further incorporated for providing flashing, moving or otherwise dynamic light distribution patterns.



BEAMFORMER FOR A REMOTELY ILLUMINATED LIGHTING SYSTEM AND METHOD

Background of the Invention

1. Cross-Reference to Related Applications

The present application is related to commonly assigned United States Patent Application Serial No. 08/733,940 entitled "Integrated Beamformer and Method of Manufacture Thereof" filed October 21, 1996, the disclosure of which is hereby expressly incorporated herein by reference. The present application is also related to commonly assigned United States Patent Application entitled "Lighting System Sequencer and Method" filed of even date herewith, the disclosure of which is hereby expressly incorporated herein by reference.

2. Field of the Invention

The present invention relates generally to lighting systems. More particularly, the present invention relates to remotely illuminated lighting systems, and to a beamforming device, or luminaire, for use in a remotely illuminated lighting system to provide a controlled, precise and dynamic light distribution pattern.

3. Discussion of the Related Art

Airports incorporate a system of lighting to provide guidance to approaching aircraft. The conventional aircraft approach lighting system (ALS) includes groups of incandescent lamps distributed over a field, lighting several thousand feet of the approach to the runway within specific requirements for angular light distribution, color and intensity. A major problem with the use of incandescent lamps in the ALS lies with monitoring the many light sources, i.e., each incandescent lamp, for failure. The availability of the ALS is dependent on the number and location of failed lamps in the system. Lamp replacement is a significant cost owing to the required human and equipment resources and the cost of the lamps.

maintenance. While, cool operating, spark free beamformers provide safer, reduced cost illumination suitable for use in any number of operating environments.

While great improvements to existing lighting system technology are at hand, further enhancements may be made through enhancement and control of the light distribution from the beamformer. For example, light distribution patterns from high intensity incandescent lamps is typically fixed and limited to a 180° distribution pattern in a horizontal plane. Certain lighting applications, such as mast head navigation lights for marine vessels, require horizontal distribution patterns in excess of 180°, and thus require multiple lamps or beamformers. It would also be desirably to have the ability to adapt the light distribution for a particular application, and to be able to readapt the light distribution for another application. Still more desirable would be an ability to dynamically alter the light distribution pattern. Present systems for providing dynamic light distribution patterns, such as rotating beacon applications, require mechanical drive elements for physically rotating the light source. Thus, there is a need for a beamforming device that provides enhanced range yet precise lighting distributions. There is a further need for a beamformer for use in a remotely illuminated lighting system, which provides a precise, adaptable and dynamic light distribution pattern.

Objects of the Invention

It is therefore a primary object of the invention to provide a beamformer having an enhanced light distribution pattern.

It is also a primary object of the invention to provide a beamformer having a highly precise light distribution pattern.

It is an additional object of the present invention to provide a beamformer adaptable to a remotely illuminated lighting system and which provides a highly precise light distribution pattern.

Still another object of the present invention is to provide a beamformer having an adaptable light distribution pattern.

Yet another object of the present invention is to provide a beamformer having a dynamic light distribution pattern.

Figure 5 is a schematic representation of a second alternative embodiment of the reflective element shown in Figure 2;

Figure 6 is a schematic representation in side elevation of a beamformer illustrating the non-imaging light transformer, holographic diffuser and reflective element thereof in accordance with an alternative preferred embodiment of the present invention;

Figure 7 is a schematic perspective representation of a beamformer illustrating the non-imaging light transformer, holographic diffuser, diffusion mask and reflective element thereof in accordance with an additional alternative preferred embodiment of the present invention;

Figure 8 is a plan view of the diffusion mask shown in Figure 7 and an associated light distribution pattern;

Figure 9 is a schematic perspective representation of a beamformer illustrating the non-imaging light transformer and reflective element thereof in accordance with another alternative preferred embodiment of the present invention;

Figure 10 is a perspective view of a diffusion mask in accordance with an alternative preferred embodiment of the present invention; and

Figure 11 is a schematic perspective representation of a beamformer illustrating the non-imaging light transformer and reflective element thereof in accordance with yet another alternative preferred embodiment of the present invention.

Detailed Description of the Preferred Embodiments

1. Resume

A remotely illuminated lighting system distributes from a central illumination source light signals to remote light distribution devices. Each remote light distribution device, or beamformer, is adaptable to produce a highly precise distribution pattern from the light signals. The distribution pattern may be easily adjusted in both horizontal and vertical directions. In a first preferred arrangement, each beamformer is coupled via a fiber-optic cable to the central light source and includes a non-imaging light transformer

optical splitter and a network of fiber-optic bundles for conducting light signals from illuminator 20 to one or more beamformers 14.

Each of first light source 22 and second light source 24 preferably generate a source of energy in the visible range that is concentrated by an elliptical or parabolic reflector to a focal spot. The high efficiency coupler 20 couples the light concentrated in the focal spot into the optical fibers that form light delivery system 22. As shown, light source 24 is preferably a redundant light source. Direct optical regulator 26 is preferably coupled to optical switch 28 to monitor the light output of both first light source 22 and second light source 24. Under normal conditions, only first light source 22 is supplied electrical power and thus is the only source of light signals. Should first light source 30 fail, the failure is detected by direct optical regulator 26 which causes signals to be sent to: 1) power supply 20 to cut power to first light source 22 and to provide power to second light source 24 and 2) optical switch 28 to receive light energy from second light source 24 for coupling to high efficiency coupler 30.

3. Beamformer Assembly

With the exception of beamformer 14, the forgoing described elements of the present invention are more fully disclosed and preferred constructions therefore are discussed in the afore-mentioned United States Patent No. 5,629,996, and reference is made to the description contained therein. With reference now to Figure 2, a beamformer 14 in accordance with a first preferred embodiment is shown in schematic detail. As seen in Figure 2, beamformer 14 includes a light-tight housing 100 having a generally cylindrical shape including a closed bottom 102, an open top 104 and a cylindrical cavity 106. A flanged aperture 112 is formed in bottom 102 for receiving a fiber-optic cable coupler 108. Fiber-optic cable coupler 108 is a suitable fiber-optic cable coupler for coupling beamformer 14 to a fiber-optic cable 110 of light delivery system 16. Housing 100 is preferably formed from plastic material using an appropriate molding process.

Disposed and secured to top 104 is a transparent annular window 110 preferably constructed from a transparent plastic material. Annular window 110 axially extends

cavity 106 and includes a reflective element 112 enclosing an end 114 of annular window 110. Reflective element 112 is preferably cone shaped with a pinnacle 116 thereof substantially aligned with a centerline of housing 100 and directed inwardly toward cavity 106. Reflective element 112 includes an angled reflective surface 118. More particularly, and best seen if Figures 3 - 5, reflective surface 118 is formed to an included angle with respect to the centerline of housing 100. Reflective element 112 may be formed using either a dielectric or a metallic configuration for providing reflective surface 118.

Disposed and secured within cavity 106 is a non-imaging light transformer 120. Light transformer 120 includes a body portion 126 having a light entrance 122 and a light exit 124. Light entrance 122 is aligned closely adjacent coupler 108, and hence, closely adjacent an end 128 of fiber-optic cable 110 for coupling light signals from fiber-optic cable 110 into light transformer 120. Light transformer 120 is preferably of a construction shown and described in the afore-mentioned U.S. Patent No. 5,629,996 for reducing the light flux density per unit area so as to optimize the energy of the light coupled along fiber-optic cable 110 for its intended use in beamformer 14. Light transformer 120 may also be of the construction shown and described in the afore-mentioned United States Patent Application Serial No. 08/733,940. The distributed light signals 130 exit light transformer 120 at light exit 124 and are directed onto reflective surface 118 and are reflected outwardly through annular window 110 forming light distribution pattern 132. In the embodiment shown in Figure 2, light distribution pattern 132 extends radially from beamformer 14 in a 360° horizontal pattern having a vertical distribution angle .

Referring now to Figures 3 - 5, the vertical elevation of light distribution pattern 132 may be adjusted in beamformer 14 by adjusting the configuration of reflective element 112. Figure 3, illustrates reflective element 112 as shown in Figure 2. That is, reflective element 112 is formed with an included angle of 90°. A light ray 134 directed axially along housing 100 and striking reflective element 112 is reflected at an angle to the centerline of housing 100 that is equal to angle or also 90°. The

beamformer 140 has a vertical distribution angle 2 greater than . It should be appreciated that many other light shaping patterns may be introduced by holographic diffuser for shaping and controlling the light distribution pattern of beamformer 140, and for example, to concentrate the light distribution pattern into a narrow vertical distribution.

Referring now to Figures 7 and 8, a beamformer 150 provides a horizontal light distribution pattern 158 of less than 360°. Beamformer 150 includes positioned between holographic diffuser 142 and reflective element 112 a mask element 152. Mask element 152 includes a substantially transparent portion 154 and a substantially opaque portion 156. Mask element 152 may be formed from a suitable low loss optically transparent material to which a mask coating is applied in the appropriate configuration. The effect of mask element 152 is to block light rays exiting light transformer 120 at light exit 124 from reaching reflective element 112 in predetermined regions. The resulting light distribution pattern 158 thus includes a region 162 in which light rays are reflected from reflective element 112 as described, and a region 160 in which no light rays are reflected. Beamformer 150 is thus suitable for applications requiring a less than 360° horizontal light distribution pattern, such as marine vessel mast head navigation lights. And, in contrast to the previously noted prior art, a greater than 180° horizontal light distribution pattern is possible with a single beamformer 150. Holographic diffuser 142 is shown and is included to provide a desired vertical distribution angle 2; however, it may not be required in every application of beamformer 150. Furthermore, it will be appreciated that holographic diffuser 142 may be coated or otherwise provided with an opaque region to accomplish the function of mask element 152.

The light distribution pattern 158 may also be achieved utilizing the beamformer 170 shown in Figure 9. Beamformer 170 includes light transformer 120 and holographic diffuser 142 and reflective element 172. In all general aspects, reflective element 172 is identical to reflective elements 112, 136 and 138. Reflective element 172 differs in that a portion 174 of reflective surface 118 is made non-reflective. This may be accomplished by a number of methods including 1) not coating portion 174 with reflective material, 2) applying a non-reflective coating to surface 118 in the area of

adjustment may be attained by including less or more cells, respectively, to mask 182. In addition, the cells need not be formed as angular sections of mask 182, but may be formed in various configurations providing a wide variety of light distribution patterns.

In certain applications it may be necessary to provide a colored light. For example, navigation lights are colored red for port, blue for starboard and white for stern, respectively. Obstruction lights are typically colored red. In this regard, beamformers 14, 140, 150 170 and 180 may include a suitable colored filter disposed between light transformer 120 and reflective element 112. In the alternative, colored filters or colored light sources may be employed in illuminator 20.

Many changes and modifications could be made to the invention without departing from the fair scope and spirit thereof. The scope of some changes is discussed above. The scope of others will become apparent from the appended claims.

8. The beamforming device of claim 1, comprising a mask element disposed between the light transforming member and the reflective element, the mask including a plurality of regions, each region having a first substantially opaque state and a second substantially transparent state.

9. The beamforming device of claim 8, wherein the plurality of regions are responsive to an electrical signal for transitioning from the first state to the second state.

10. The beamforming device of claim 9, comprising a controller for selectively applying an electrical signal to selected ones of the plurality of regions.

11. The beamforming device of claim 1, wherein the light source comprises a remotely located illuminator and a light pipe.

12. The beamforming device of claim 1, wherein the reflective element has a generally conical configuration.

13. The beamforming device of claim 12, wherein the reflective element has a substantially 90° included angle.

14. The beamforming device of claim 12, wherein the reflective element has an included angle less than 90°.

15. The beamforming device of claim 12, wherein the reflective element has an included angle greater than 90°.

23. The apparatus of claim 22, wherein the reflector has a substantially 90° included angle.

24. The apparatus of claim 22, wherein the reflector has an included angle less than 90°.

25. The apparatus of claim 22, wherein the reflector has an included angle greater than 90°.

26. A method for forming a light distribution pattern comprising the steps of:
A) providing a light signal;
B) transforming a characteristic of the light signal;
C) directing the light signal toward a reflective element; and
D) distributing the light signal from the reflective element in a predetermined light distribution pattern.

27. The method of claim 26, wherein the step of transforming a characteristic of the light comprises transforming a flux density of the light signal.

28. The method of claim 26, further comprising, between Step B and Step C, the step of shaping the light signal.

29. The method of claim 28, wherein the step of shaping the light signal comprises passing the light through a light shaping device.

30. The method of claim 28, wherein the light shaping device comprises a holographic diffuser.

2) an optical switch coupled to the first light source and the second light source for selectively coupling light signals from the first light source and the second light source to an optical coupler;

B) a light distribution system having:

1) an input coupled to the optical coupler,

2) a plurality of outputs, and

3) at least one light distribution path coupled at a proximal end to one of the plurality of outputs; and

C) a beamformer having:

1) an input coupled to a distal end of the at least one light distribution path;

2) a housing having a generally cylindrical shape, a closed bottom and an open top, the housing defining a cylindrical cavity;

3) a light transforming member disposed within the cylindrical cavity, the light transforming member having an optical entrance adjacent to the input and a light distributing optical exit projecting toward the top;

4) an optically transparent annular member secured to the top;

5) a reflector secured to the annular member, the reflector having a reflective surface disposed toward the light distributing optical exit; and

6) a light shaping member disposed between the light transforming member and the reflector.

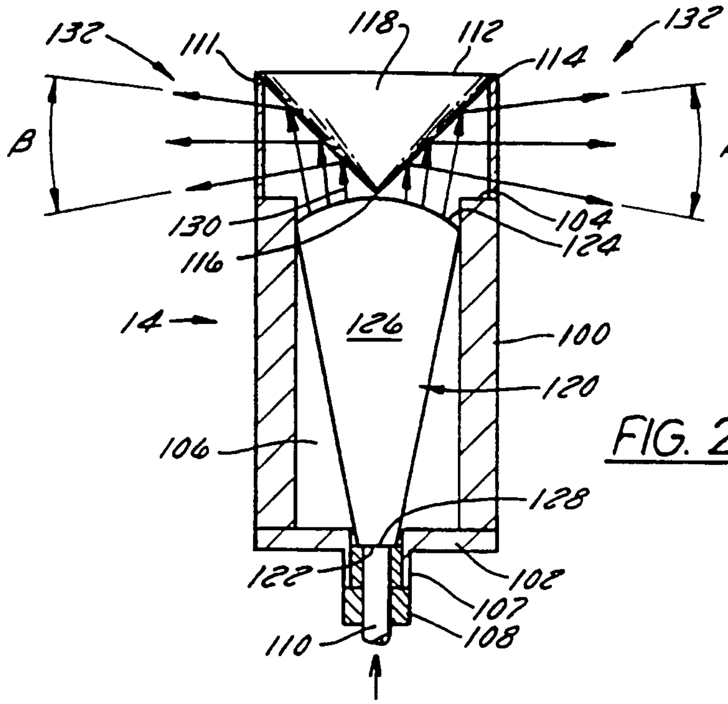
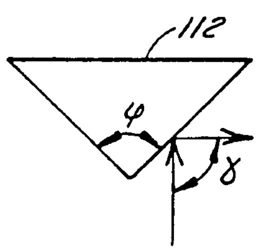
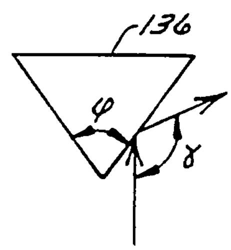


FIG. 2



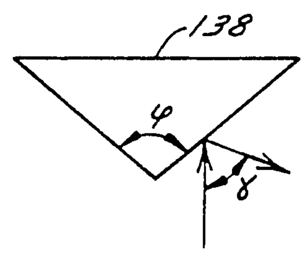
$\varphi = 90°$
$\gamma = 90°$

FIG. 3



$\varphi < 90°$
$\gamma > 90°$

FIG. 4



$\varphi > 90°$
$\gamma < 90°$

FIG. 5

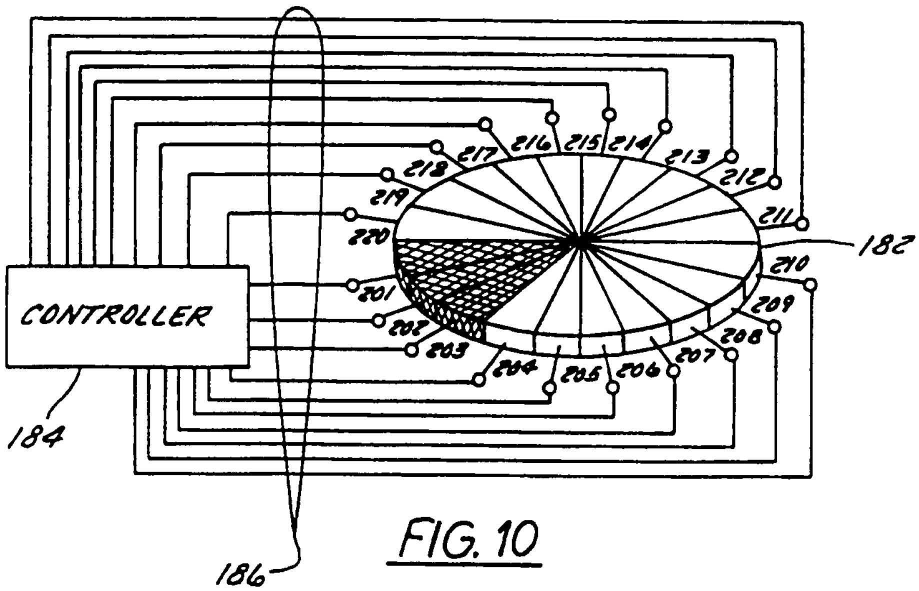

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FIG. 10

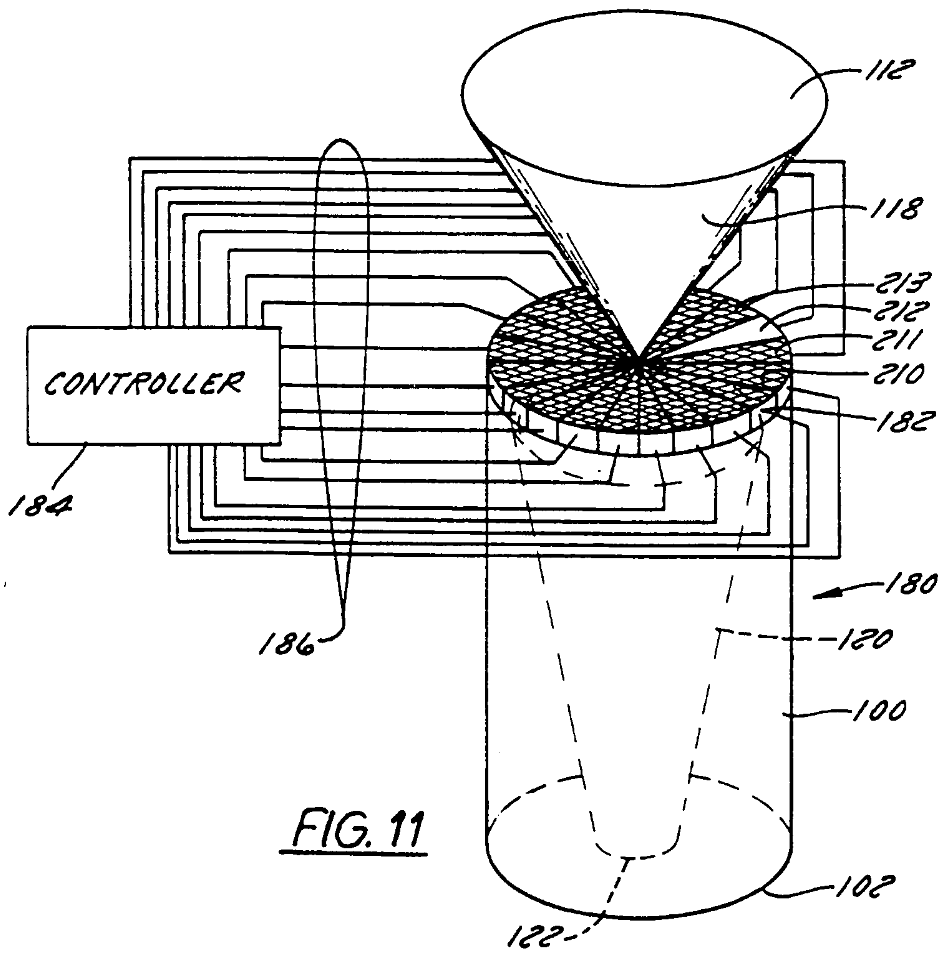
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FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/02756

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

362/560, 552, 558